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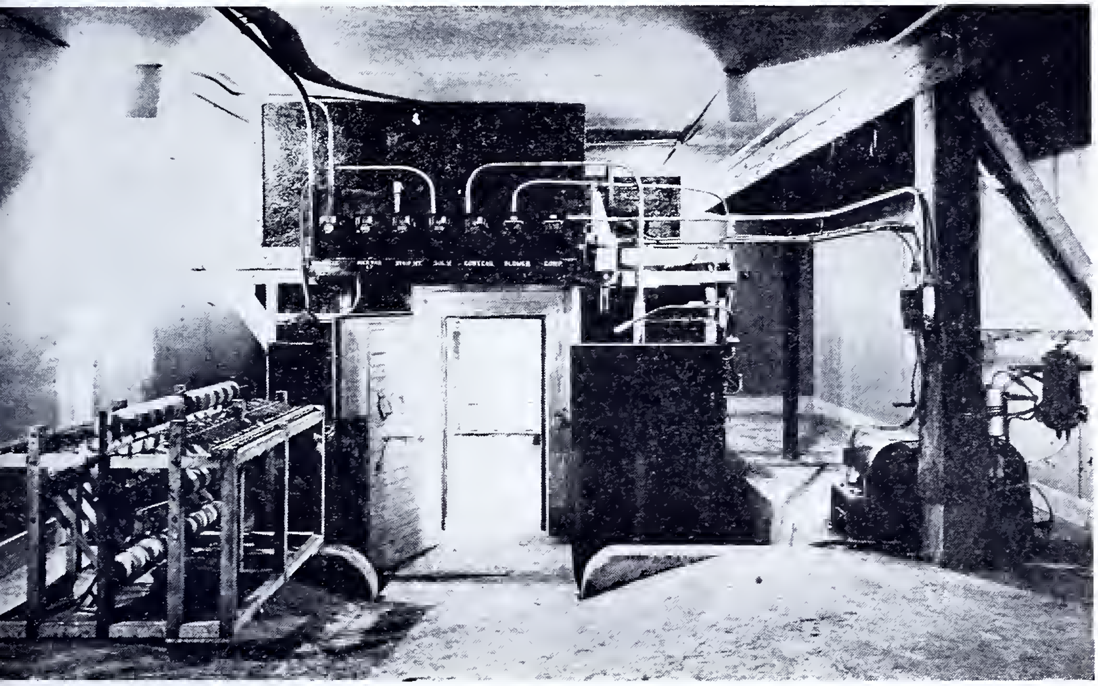
THE CLIMOACTOMETER

A DEVICE DESIGNED TO MEASURE THE EFFECTS OF VARIOUS METEOROLOGICAL FACTORS UPON THE ACTIVITY AND GENERAL PHYSIOLOGY OF ANIMALS



Research Circular No. 1

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PENNSYLVANIA GAME COMMISSION
Harrisburg, Pa.

●

1938

Pennsylvania Game Commission

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THE CLIMOACTOMETER

A DEVICE DESIGNED TO MEASURE THE EFFECTS OF VARIOUS METEOROLOGICAL FACTORS UPON THE ACTIVITY AND GENERAL PHYSIOLOGY OF ANIMALS

By
Richard Gerstell
Chief of the Division of Game Research and Distribution

INTRODUCTION

General climatic conditions undoubtedly play a major role in the distribution of animal life over the earth's surface. For instance, highly complex terrestrial plant and animal communities are never found in the polar regions, where low temperatures and extremely short growing seasons provide a physical environment which relatively few forms of life can endure. On the other hand, the tropics present a peculiarly favorable climate in which the most complex biological associations flourish. Similarly, in the temperate zones winter is typified by dormant plants and relatively few active animals, while summer is marked by an abundance of growing plants and increased numbers and varieties of animals.

Just how climatic conditions govern the distribution of animals is not fully understood. In some cases, the physiological powers of the various species are such that they can successfully maintain themselves only within certain very definite environmental limits. In others, the animal is indirectly controlled by the extent to which the climate allows for the development of those plant forms required for food and cover. In the majority of cases, however, the process involves a combination of physiological adjustment and the satisfaction of food and cover requirements.

Daily and seasonal changes in meteorological conditions obviously effect the activity of animals. Several days of extreme winter cold will frequently cause cottontail rabbits to seek the shelter of a hole or burrow, while unusually warm summer days drive pheasants, quail and other forms from the more open areas into dense shade. The approach of winter "forces" the bear into hibernation and the goose southward into warmer climes, while the return of milder weather "leads" bruin from his winter den and the goose to the breeding grounds in the far north.

Were it possible to measure both quantitatively and qualitatively the effects of the various physical factors of the environment upon the activity and general physiology of animals, many biological problems quickly could be solved. Thus, those persons entrusted with the management of our wildlife resources would better be able to adopt and apply sound measures designed for their conservation and increase.

To date, by far the greatest percentage of wildlife research has been concerned with the *activity* of the various game and fur-bearing animals. It has dealt with the dates and routes of migration, with feeding habits, with breeding season phenomena, with predation, with the determination of cruising radii, and other similar problems. *Each and every one of these represent merely separate phases of animal activity.*

The data has been collected very largely by the observational method. With the exception of the work done by Wight and his associates (1933) at Northville and Williamston, Michigan, and a few other studies, the exact meteorological conditions under which the observations were made have, however, not been recorded.

Furthermore, with the exception of certain trapping and banding techniques carried out by Lincoln (1933), Dalke and Sime (1938) and others in connection with migration and range investigations and the work done by Gerstell and Long (1939) in comparing wild turkey poults of two different strains, the *wildlife* workers have made few attempts to *measure* quantitatively or qualitatively the activity observed.

It seems evident that *until the effects of varied climatic conditions upon the activity and general physiology of game birds and mammals can accurately be determined,* food and cover development programs may prove highly inefficient; census figures may contain high degrees of error; and open seasons for the trapping of fur-bearing animals may defeat their own purpose. Recognizing this, the Pennsylvania Game

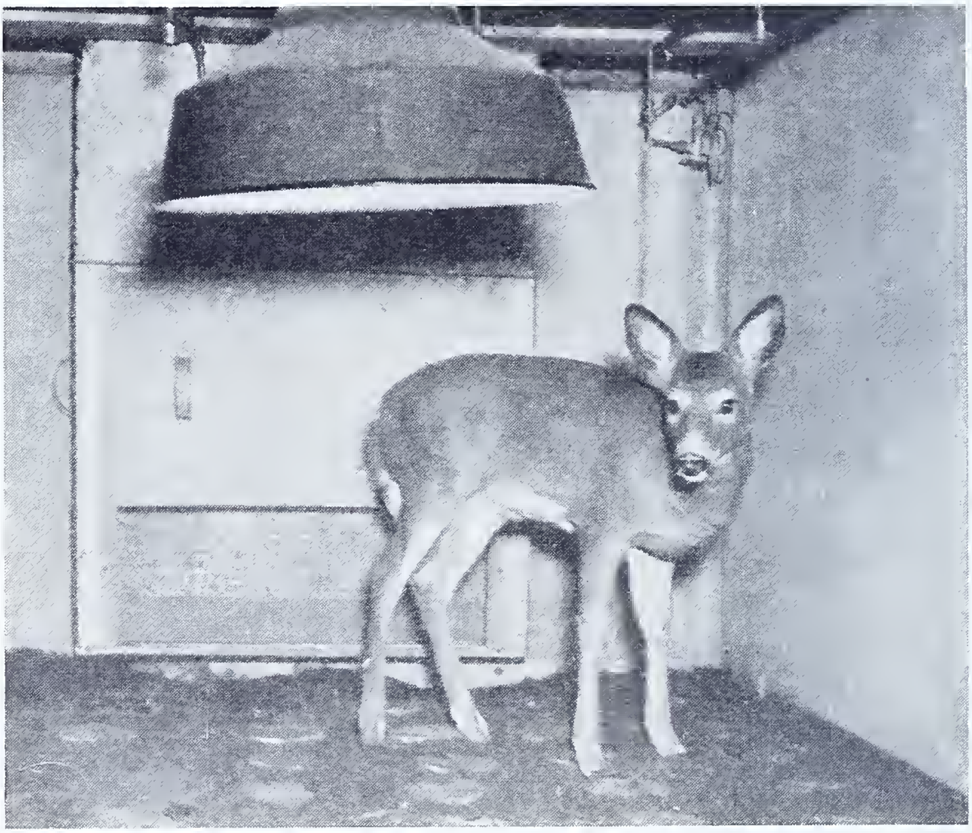


Figure 1

A deer in the climoactometer.

Commission in late 1937 approved a series of experiments designed to throw some light on the subject. This has resulted in the development of a device, technically termed a climoactometer, designed to measure the effects of various meteorological factors upon the activity and general physiology of animals, both large and small.

The construction and operation of this equipment does not, of course, represent the first attempt to measure quantitatively and qualitatively the activity of animals, and the principles employed are not entirely new in every detail. Wight (1938) discusses certain of the methods he and other biologists have used in measuring the activity of animals, principally small mammals, while Shelford (1929) and others have controlled the temperature, humidity and light in small experimental chambers. A study of these reports will reveal certain similarities which may be found in the operating principles employed in the climoactometer.

ACKNOWLEDGEMENTS

The construction of any apparatus as large and as complicated as the climoactometer required the cooperative efforts of technical experts in several different fields. Accordingly, the author acknowledges with sincere thanks the invaluable advice and assistance graciously offered by the following individuals, organizations and corporate concerns:

Joseph Call of the Elliott-Lewis Corporation of Philadelphia, distributors of General Motors air conditioning equipment, for aid in the development of plans and specifications for the climatic chamber and in the supervision of its construction; Joseph H. Palmer and Roger M. Latham, the author's assistants in the Pennsylvania Game Commission, for general assistance in the planning and construction of the apparatus; John S. Yard of the Mundet Cork Corporation for help in insulating the climatic chamber; E. C. Marshall of the Dauphin Electric Company, Harrisburg, Pennsylvania, for suggestions relative to the lighting system and other electrical devices; Arthur N. Brent, Chief Engineer, Penn-Harris Hotel, Harrisburg, Pennsylvania, for technical advice; Max Kroeger of the Allis-Chalmers Corporation for suggestions as to gearing; Earl S. Greenwood, Superintendent of the Loyalsock State Game Farm, for many practical suggestions and assistance in construction; Robert Weeks and Everett C. Henderson of the National Youth Administration of Pennsylvania for making available a fully-equipped wood-working shop and arranging for manual assistance by employes of that organization; The M. E. Housel Company of Williamsport, Pennsylvania, Delco-Frigidaire Distributors, for installation of the refrigeration, heating and humidity apparatus; and The General Motors Corporation, The General Electric Corporation, The Minneapolis-Honeywell Heat Regulator Company, The Charles F. Bond Company and other commercial firms which offered advice and supplied various pieces of equipment used in construction of the apparatus.

Grateful acknowledgment is also made to Professor H. M. Wight of the University of Michigan for constant advice, suggestions and review of this paper as well as to Professor S. A. Graham of the same institution for criticism of the manuscript.

LOCATION

The apparatus is located at the Commission's Loyalsock State Game Farm in Lycoming County, Pennsylvania, approximately five miles north of the town of Montoursville and eight miles from the City of Williamsport.

This north-central Pennsylvania site was selected because holding space for various experimental animals was already available there, while in the immediate vicinity all the State's principal game species, both of farm and forest varieties, naturally live in fair abundance, thus affording ideal opportunities to check by field observations results obtained from the laboratory studies.

The equipment was placed in an insulated room in the basement of a large barn where storage space, running water and electricity were available and a fairly constant year-round temperature was assured.

FUNCTIONAL UNITS AND DERIVATION OF NAMES

The climoactometer consists of three major functional units, the climatic chamber, the activity relays and the actometer. Within the chamber the experimental animals are subjected to almost any desired climatic simulation, while the activity relays transmit "indicators" of the animals' activity to the actometer which automatically records them on moving ribbons of paper. Thus the apparatus measures the effect of various meteorological factors upon the activity of animals. By condensation of the names of the functions performed the name climoactometer was coined.

In the paragraphs which follow the reader will find both brief and greatly simplified descriptions of the construction and operating principles employed in the apparatus. In their perusal, as well as in the study of the various diagrams presented herewith, one must remember that they have been prepared chiefly for the purpose of making them easily understood and that they consequently do not portray many important minute details, nor are they in every respect represented in their exact relationships one to the other.

THE CLIMATIC CHAMBER

(The numbers in parentheses refer to construction details shown in Figure 2, Page 8.)

The climatic chamber is twelve feet long, eight feet wide and five feet high, inside measurements. It is placed on a two-inch plank floor laid on "sleepers" six inches square. All four walls, as well as the floor and ceiling, are composed of two layers of cork each four inches thick (22), sealed with hot asphalt and supported by a wooden framework (5 & 26). A three-inch cement floor (11) poured on top of the cork is sloped toward three drains located at one end of the chamber. Entrance is through a heavily insulated refrigerator door (6) at one end.

The temperature range of the chamber extends from —20° F. to +120° F. The refrigeration system employes a three horse-power compressor (1). In copper tubes (2) the refrigerant passes to the cold plates (23) which form the two sides and rear end of the experimental area.

Heat is supplied by four electrically operated strip-heaters (9) located in the wind duct which will be described below.

The temperature within the chamber is automatically controlled by setting a series of thermostats located within a specially constructed control cabinet (3) outside the chamber. This mechanism, controlling both the refrigeration and the heating units, is so sensitive as to maintain the chamber temperature at any desired point in the range with a variation of less than ±1° F. The maximum cooling rate exceeds 20° F. per hour, while the maximum heating figure is approximately 17° F. per hour.

The humidity is controlled by an humidistat (7) located inside the chamber alongside the thermostat bulbs, but controlled from without. This instrument operates a set of nozzles (8) through which cold water is emitted in the form of a very fine spray. Dehumidification is brought about by chemical methods.

The precipitation system (20) is composed of a series of pipes with special outlet nozzles through which, by variation in the pressure, water may be passed as a "mist," a "light rain," or a "heavy downpour." By proper regulation of the temperature within the chamber, this device allows for the production of "ice storms" and attempts are being made to develop a method whereby "snow storms" may also be reproduced.

The lighting system consists of a series of six lamps controlled from without by switches and rheostats. In the center of the chamber there is a large reflector receptacle holding one 400-watt General Electric, Type H, mercury vapor lamp (15) and three 100-watt incandescent lamps (16). These are supplemented by two General Electric, Type S-2, ultra-violet lamps with reflectors (12 & 19) located at either end of the chamber.

The light switches may either be operated manually or attached to automatic clocks in order to simulate the rising or setting of the sun. The types of lamps employed and their method of connection make possible wide variation both in respect to intensity and character of the rays.

The movement of air through the chamber is brought about by means of a large blower (10) located within a series of metal ducts (14 & 18) mounted in the form of a super-structure and insulated with six inches of cork (24). The blower is driven by a variable speed, one-half horse-power motor (13-Top Elevation) mounted on top of the exterior of the chamber.

The chamber and ducts form a "closed" system through which the air constantly circulates and, as desired, may, or may not be, "blown" over the experimental animals in the form of "wind."

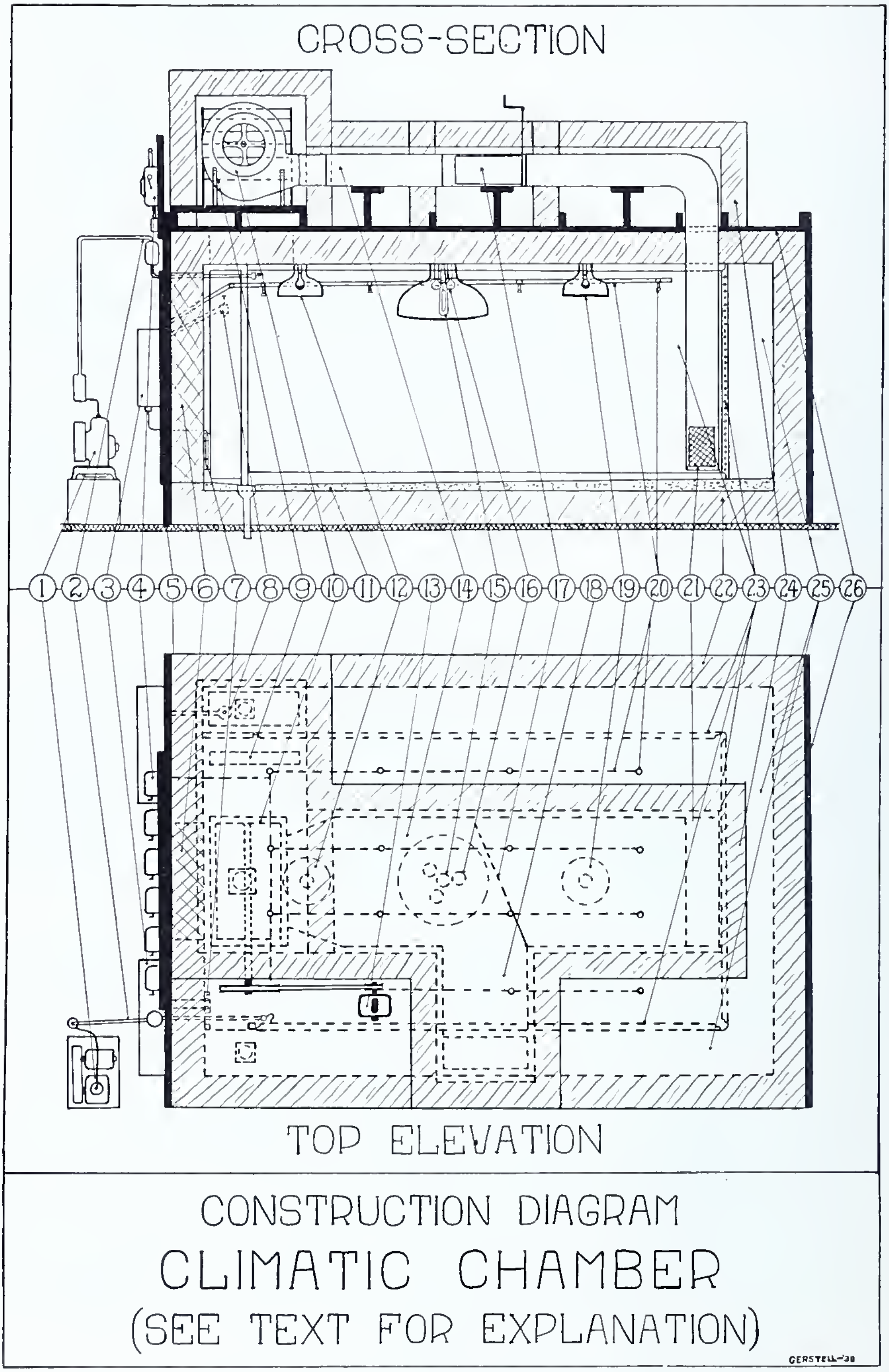
The air is drawn by suction from the experimental area through a screened opening extending between the front wall of the chamber and the end of one of the lateral cold-plates in that corner nearest the compressor (1). From this point it passes through the space (25) between the cold-plates (23-Top Elevation) and cork wall (22-Top Elevation) down one side, across the back, and up the other side to the vicinity of the humidity nozzles (8) in that corner of the chamber opposite the original point of exit from the experimental area. From the vicinity of the nozzles, the air is drawn upward through the covered duct, through the rack of strip heaters (9) and finally into the blower (10). From the blower it is forced into the main air duct (14).

If it is desired to "subject the experimental animals to wind," the by-pass damper (17) is so turned as to prevent the entry of the air into the by-pass duct (18-Top Elevation) and send it directly along the main duct until it leaves this channel through screened and damper-equipped exits (21) and enters the experimental area. It blows the length of the chamber as "wind" and once again passes behind the plates at the point first mentioned and continues to circulate through the train just described.

If it is desirable to have the experimental animals subjected to no air movement, the by-pass damper (17) is turned across the main duct (14) deflecting the air into the by-pass duct (18-Top Elevation) from which it is forced down behind the cold plates and through suction and push is again and again passed through the circuit.

The circulation of air just described not only allows for the simulation of winds of slightly more than twenty-five miles per hour velocities (and through variation of motor speeds and damper manipulation, any desired lower velocities), but also tends to reduce to a minimum the effects of air "layering." Thus equal temperatures are maintained throughout the entire chamber.

The chamber is electrically operated with each control unit separately wired and through a series of switches (4) capable of independent operation, or disconnection, which allows for the maximum operating simplicity and safety.


CROSS-SECTION
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TOP ELEVATION
CONSTRUCTION DIAGRAM
CLIMATIC CHAMBER
(SEE TEXT FOR EXPLANATION)
GERSTELL-'38

Figure 2

KEY
FIGURE 2

The construction details indicated in Figure 2 (opposite) and mentioned in the description (see text) are as follows:

Number	*Construction Detail*
1	Refrigerating compressor
2	Refrigerant tubes
3	Control panel
4	Electric switches
5	Wooden framework
6	Refrigerator door
7	Humidistat
8	Humidity nozzles
9	Electric strip heaters
10	Blower
11	Cement floor
12	Ultra-violet lamp
13	Blower motor
14	Main air duct
15	Mercury vapor lamp
16	Incandescent lamps
17	By-pass damper
18	By-pass air duct
19	Ultra-violet lamp
20	Precipitation system
21	Air exits
22	Cork insulation (eight inches in thickness)
23	Refrigerating cold plates
24	Cork insulation (six inches in thickness)
25	Air space
26	Wooden framework

In addition to controlling the "meteorological" conditions within the chamber, practically any desired "habitat" can also be reproduced. Soil of different kinds and in varying depths may be placed upon the floor, while living plants may be rooted therein and thus cover of various types built up upon its surface. In short, environmental conditions of almost any type may with reasonable accuracy be simulated within the chamber. Furthermore, the chamber has been so constructed as to allow for the insertion of a metabolism hood should such action later prove desirable.

THE ACTIVITY RELAYS

(The numbers in parentheses refer to construction details shown in Figure 4, Page 12.)

Once the desired environmental conditions have been established and the experimental animals subjected thereto, the next step is to measure their reactions, especially their muscular activity as evidenced by squatting, walking, running, etc. This requires the automatic transmission of the activity "indicators" to the recording device, or actometer. It is accomplished through two somewhat similar electrical methods.

The first and most important method employs a large number of relays placed in any desired positions in the "ground." They are set in the soil with their top surfaces flush with the level of the earth. As the animals place their weight upon the relays, an electric circuit is completed and the activity pens of the actometer write upon moving ribbons of paper, as will hereinafter be described.

The construction of the relays is diagrammatized in Figure 4. They are built

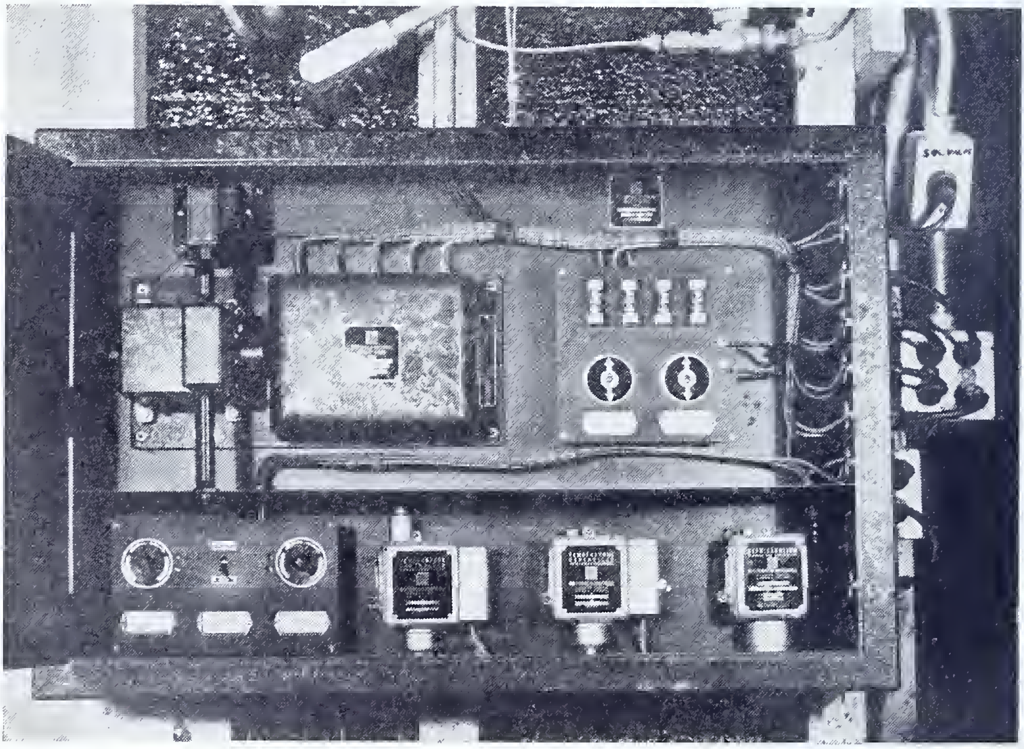

FIGURE 3

Interior of the control cabinet.

chiefly of wood and consist of two principal parts, the shell (2) and the plunger (7). The plunger is suspended within the shell by elastic supporting bands (14) which can be attached to any one of a series of tension hooks (1) whereby the ease of the plunger's motion is readily adjusted. Fastened to the lower surface of the plunger is a circular upper contact disc of brass (4). Directly below this the lower contact disc (12) is suported by adjustable set-screws (5). It is firmly held in position by a tightly stretched elastic tension band (13) threaded through two sets of attachment hooks (3). A flexible, woven wire (9) connects the cross rod (11) of the upper contact disc (4) with one of the cable binding posts (10), while a second wire of the same type (6) connects the lower contact disc (12) to the other cable post. A weather-proofed, two-way cable is brought up through the cable entry (8) and one lead is attached to each of the two cable posts.

The relays operate in the following manner: The cable carries in one lead the charge from one side of an eighteen-volt electric outlet, while the second lead is attached to one side of a solenoid which operates a writing pen, as will later be explained. The other side of the solenoid is attached to the second side of the source of current. Just so long as the upper and lower contact discs are not in contact one with the other, the circuit is "broken" and the solenoid is not in operation. Whenever the weight of an animal upon the relay plunger forces the plunger downward so bringing the two discs into contact with each other, the circuit is "completed" and the solenoid becomes operative. The solenoid remains in operation as long as the circuit is "complete." This represents the total length of time during which the animal's weight rests upon the plunger.

When in use, the relays are covered over with a very light, unusually flexible, weatherproof cover made of oiled silk (Figure 5). This is held in place by an adjustable metal ring. It not only renders the unit waterproof, but prevents the entry of dirt, excreta and other materials which might easily interfere with proper operation. Also, it makes possible the concealment of the location of the relays by covering them lightly with soil.

Through variations in the adjustment of the cover, the tension of the supporting bands and the space between the two contact discs, it is possible to set the relays so they will accurately operate under the weight of a day-old game bird as well as that of a full-grown deer.

The second method of activity measurement employed in connection with the climoactometer involves the use of rotating wheel cages, frequently referred to as "exercise wheels" or "squirrel wheels." The animal is placed in a drum-shaped cage which revolves on a stationary axle. As the animal walks, or runs, in the wheel, it rotates about the axle. Each rotation results in the "completion" of an electric circuit of short duration which, as will later be described, results in the appearance of a single dot on the actometer record·

The wheel cages differ somewhat in size and construction depending upon the species of animals used for experimentation. They are, however, similar in principle to those used by Stewart (1898), Slonaker (1908), Greenman and Durhing (1923), and H· S. Colton (1933), who worked with rats and other small mammals.

THE ACTOMETER

(The numbers in parentheses refer to construction details shown in Figure 6, Page 16.)

The actometer, which records the activity "indicators" transmitted to it through the relays, is a rather complicated device composed principally of a large number of electric solenoids each connected with separate recording pencils which write upon moving ribbons of paper.

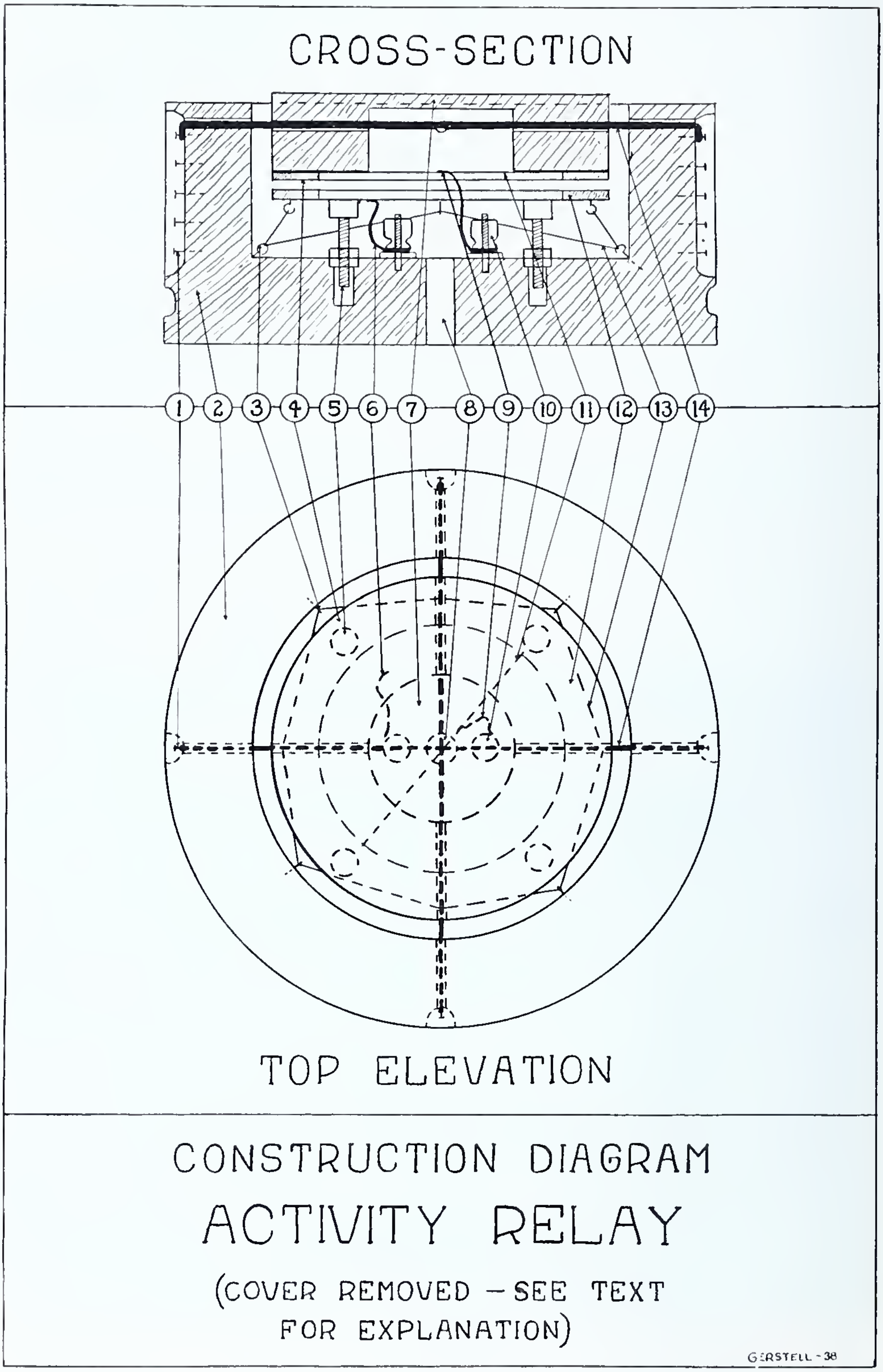
CROSS-SECTION
TOP ELEVATION
CONSTRUCTION DIAGRAM
ACTIVITY RELAY
(COVER REMOVED — SEE TEXT
FOR EXPLANATION)
GERSTELL - 38

Figure 4

KEY
FIGURE 4

The construction details indicated in Figure 4 (opposite) and mentioned in the description (see text) are as follows:

Number	*Construction Detail*
1	Tension hooks
2	Wooden shell
3	Attachment hooks
4	Upper contact disc
5	Adjustable set-screws
6	Connection wire
7	Wooden plunger
8	Cable entry
9	Connection wire
10	Cable binding posts
11	Cross rod (upper contact disc)
12	Lower contact disc
13	Elastic tension band
14	Elastic supporting bands

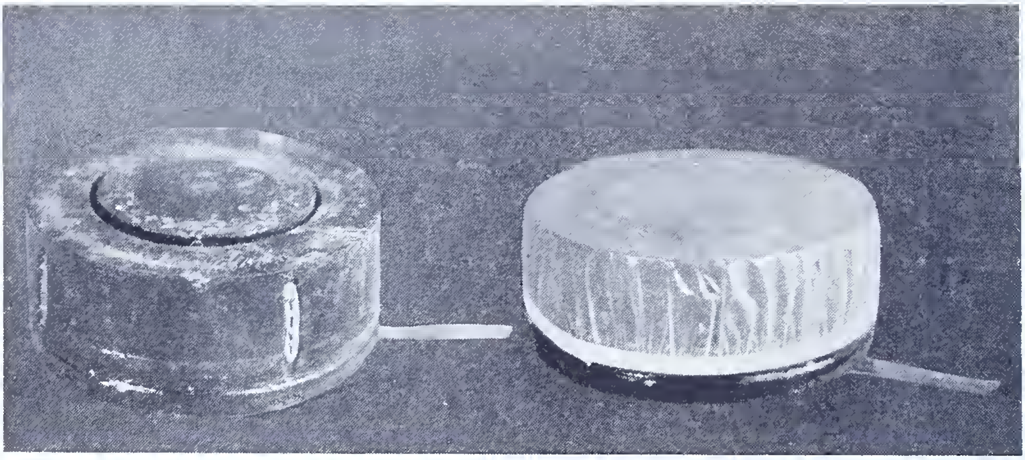

FIGURE 5

Activity relays with (right) and without left covers.

The instrument is roughly five feet long, four feet wide and three feet high, supported by a wooden framework (1). Lined along either side, in four groups of fifteen each, are sixty separate writing units. These consist of an activity recording pencil (11) attached to one end of a rocker-arm (4) mounted on a stationary axis. On the opposite end of the arm is a small wooden block placed immediately above the plunger arm of a low-voltage solenoid (2). In groups of three, the recording pencils are suspended over twenty stationary, wooden writing tables (7).

Ten rolls of ordinary adding machine paper, separated by a series of wooden dividing blocks, are threaded on a revolving supply axle (6) located in the lower central part of the device. The paper is prevented from unrolling too fast, and so becoming entangled, by means of pressure exerted by a paper brake (15-End Elevation) resting on each spool. From the supply axle (6), the paper is threaded around the left lateral rolling guide (5), then up over the left row of writing tables (7), then down and around the lower central rolling guide, then up over the right row of writing tables, then down under the upper central rolling guide, and finally up and attached to a spool on the winding shaft (8). As a result of this method of threading, all the activity recording pencils on the left-hand side of the actometer write on one side of the strip of paper, while all the pencils on the right-hand side of the machine write on the opposite side of the paper. This not only reduces the number of rolls of paper to be handled, but also effects an appreciable reduction in operating costs.

The winding shaft (8) is driven by a one-sixth horse-power electric motor (14). This is not connected directly to the shaft, but, by means of a belt (13), to a gear reducing unit (12) which cuts the speed of the motor from 1750 r.p.m. to approximately one r.p.m. The reducer is coupled to the shaft. The speed of the shaft may be doubled, or halved, merely by changing the position of the belt on the double pulleys attached to the motor and the gear reducer.

Running the length of the machine near its center, is a time recording rocker-arm (9) which supports ten time recording pencils (10) each suspended over a writing table. This rocker-arm, together with its pencils is also operated by solenoids. These are two in number one of which is situated at either end of the actometer.

Each activity solenoid (2) has separate connecting posts (3) to which any number of activity relays may be attached. The method through which the muscular activity of the animals in the climatic chamber operates the solenoids, thus automatically recording their movements, is briefly described in the succeeding paragraphs. The diagram referred to appears as the lower portion of Figure 6.

When there is no movement of the animals in the chamber and none of them are exerting any pressure upon the relays, there is no contact of the contact discs. Thus the electric circuits remain "broken" and the activity pencils rest in the "no contact" position, while the strips of paper slowly pass over the writing tables without being written upon. In other words, there is no activity and no record is traced upon the paper.

On the other hand, when the weight, entire or partial, of any animal exerts a pressure upon a relay plunger, the contact discs are brought into contact thus "completing" the circuit in which that particular relay is connected. This forces up the solenoid plunger which in turn holds the activity pencil in the "contact" position where it writes upon the paper passing over the writing tables. Just so long as the animal remains motionless on the relay, the pencil draws a continuous straight line upon the paper. If the animal remains upon the relay, but moves various parts of the body, as in feeding or stretching, the electric circuit through that particular relay is "broken" and "completed" varying numbers of times, resulting in the writing of a line broken into short dashes and dots closely spaced. If in walking or running through the chamber an animal merely steps on a relay for a fraction of a second, the written result is only a dot or short dash traced upon the paper.

The purpose of the timing device with its ten pencils is to make possible the determination of the various time factors. As already pointed out, the pencils are all attached to one long rocker-arm operated by two solenoids. Both of these are connected in a circuit which is "made" and "broken" through the rotation of specially prepared discs turned by an electrical or mechanical clock. These discs are so constructed that the circuits may be varied at will. They may be set so that they are "on" for thirty seconds, then "off" for the same length of time, then "on" again and "off" again *ad infinitum,* while for different experiments they may be "on" and "off" alternately for periods of fifteen minutes. Other timing periods of equal and unequal divisions are also possible.

In general, the time mechanism draws upon each of the ten ribbons of paper intermittent time lines which *at* regular intervals are broken *for* regular intervals. For example, if the discs are adjusted for a so-called thirty second period, the time pens draw upon the paper for thirty seconds, then they are raised from the paper for thirty seconds during which no record is written, then lowered again to draw another line "thirty seconds long," then raised again, et cetera as long as desired.

The time records just described make it possible to determine by a study of the combined time and activity lines how long an animal may have been in a given place, whether it was moving or motionless, how fast it was traveling, etc., etc. Also, when used in connection with the activity wheels, it is a simple matter to determine the number of revolutions (which show up as dots on the activity record) made during any given period of time. Thus the activity is measured both quantitatively and qualitatively.

ADDITIONAL DATA

In addition to measuring the activity of animals under varied climatic conditions, the climoactometer may also be used to determine other physiological effects produced by changes in the environmental conditions. Among these are the effects upon body temperature, respiration and heart beat as well as changes in body weight, digestive phenomena, etc.

Many of these experiments will require the confinement of the animals in small cages within the climatic chamber, but as in the case of environmenal and body temperatures, which will be read from outside the chamber by means of a precision potentiometer and thermocouples, the majority of tests will not require the presence of humans in the chamber. Thus the environmental stimuli will remain under absolute control.

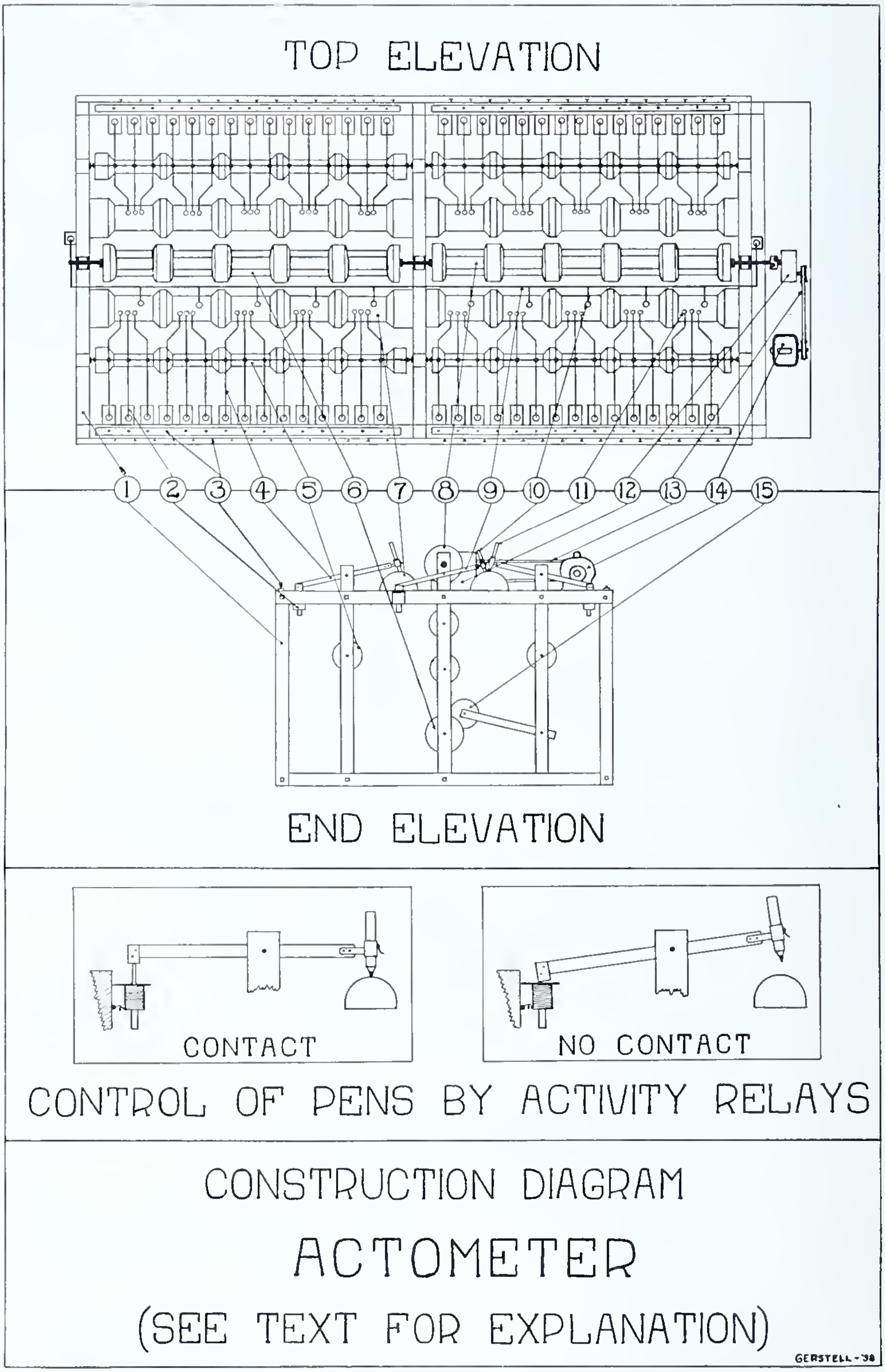
TOP ELEVATION
END ELEVATION
CONTACT
NO CONTACT
CONTROL OF PENS BY ACTIVITY RELAYS
CONSTRUCTION DIAGRAM
ACTOMETER
(SEE TEXT FOR EXPLANATION)
GERSTELL-'38

Figure 6

KEY
FIGURE 6

The construction details indicated in Figure 6 (opposite) and mentioned in the description (see text) are as follows:

Number	*Construction Detail*
1	Wooden framework
2	Low-voltage solenoids
3	Connection posts
4	Rocker-arms
5	Lateral rolling guides
6	Supply axle
7	Wooden writing tables
8	Winding shaft
9	Rocker-arm
10	Time recording pencils
11	Activity recording pencils
12	Gear reducing unit
13	Drive belt
14	Electric motor
15	Paper brake

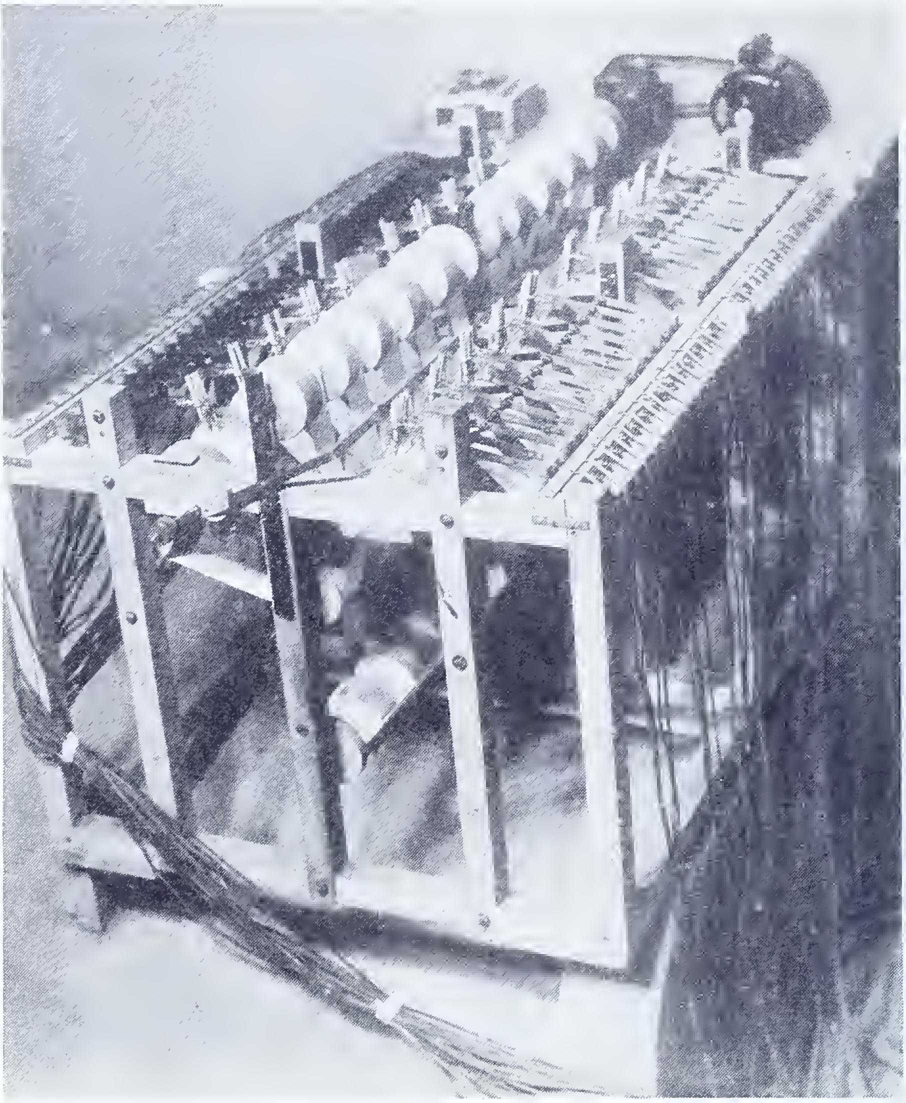

Figure 7
The actometer.

USES

The uses to which this apparatus can be put are both numerous and varied, and its operation may be expected to produce results both strictly practical and basically scientific.

The present program of experimentation calls for a carefully planned series of basic studies extended over a long period of time. These will be combined with a number of shorter tests designed to furnish immediate practical solutions to certain management problems now faced by the Game Commission.

Among the latter are experiments designed to determine the ability of various species of game to "withstand" climatic extremes; to test the efficiency of various winter game foods; to determine the value of woodchuck dens as retreats for cottontail rabbits; to compare the suitability of various strains of game animals for management practices; and numerous similar problems.

As heretofore intimated, any and all results obtained from the operation of the

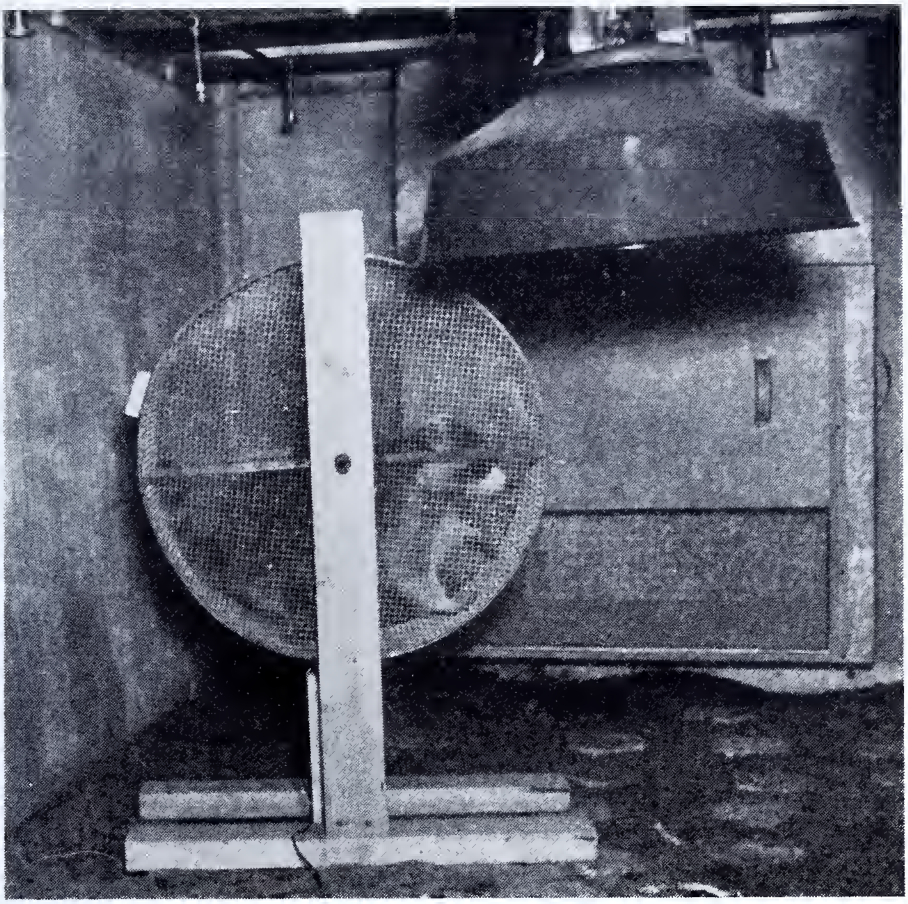

Figure 8

Raccoon in activity wheel.

climoactometer will, insofar as possible, be checked against those secured by field observations as animals subjected to laboratory experimentation cannot in every instance be expected to react the same as those in their natural habitat.

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